Inserting New Technology Into Small Missions





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Inserting New Technology Into Small Missions The Future May Not Be as Bright as Two Years Ago!



Cumulative deep space

launches

60

50

100

90

SIM B Discovery

NonNASA Mars

ssian Solar Prob US Solar Probe

2000

Mars Caching Rove

JPL Discovery Rosetta

Discovery NonNASA M



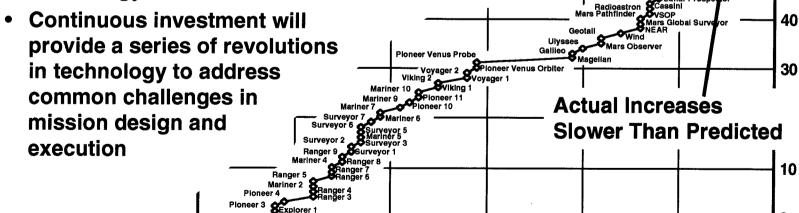
A new process is needed to allow these missions to take advantage of the technological breakthroughs that are critical to getting the cost down while increasing the science

1960



 NASA will make institutional investments in technology to benefit sets of missions

1950



1970

1980

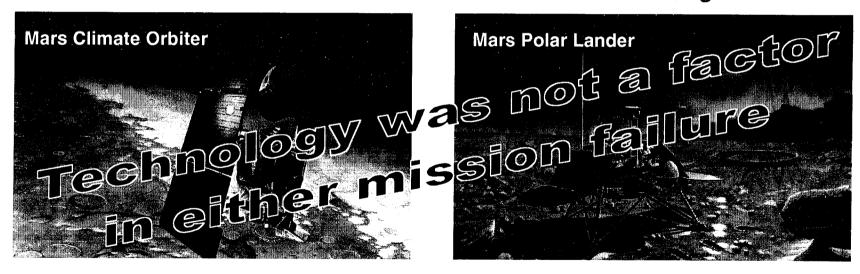
1990

2010

Inserting New Technology Into Small Missions What Happened?



- NASA experimented with "Faster-Better-Cheaper" (FBC)
- These missions were certainly cheaper and faster but "better" seems to have been forgotten
- Results included higher risk and cost overruns
- Reaction to recent deep space mission failures has been a reduction in the number of missions and an increase in the cost of the remaining missions



- Independent reports on these failures and FBC have all recommended increased emphasis on new technology for FBC missions
- NASA is still committed to FBC, but it needs to be better-defined

Inserting New Technology Into Small Missions Faster-Better-Cheaper



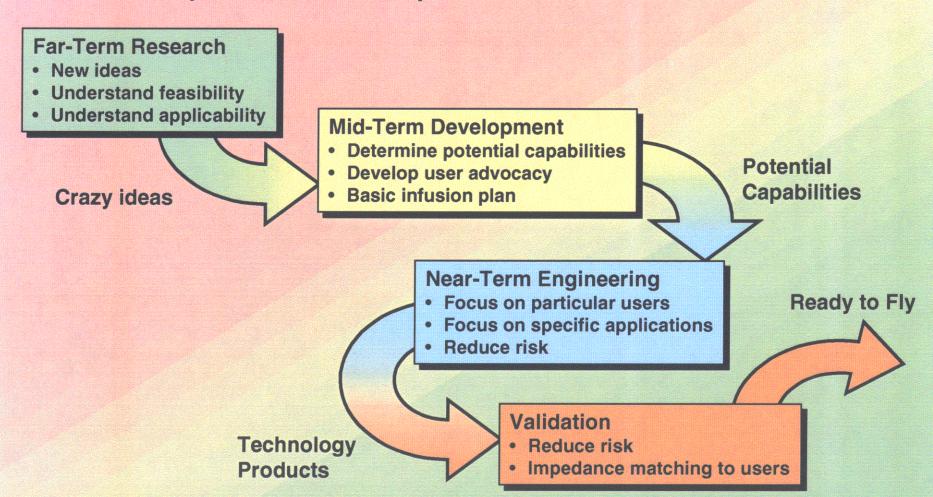
- Successful FBC requires that the latest breakthrough technology be used
 - Increase mission performance (better)
 - Reduce mission cost (cheaper)
- The key is quick, smooth infusion of new technology
 - Infusion must be quick to reduce the time it takes to design, assemble, test, and launch the mission
- Infusion times have been reduced at JPL, but they have a long way to go
 - It takes about three years to move a newly-proven technology into flight
 - This is not good enough to react quickly to changes in flight programs
- Technology must be infused from all sources not just internally
 - Other US government agencies
 - Foreign space agencies (ITAR constraints!)
 - Universities
 - Industry

JPL

Inserting New Technology Into Small Missions The Technology Life Cycle: The Four Major Epochs



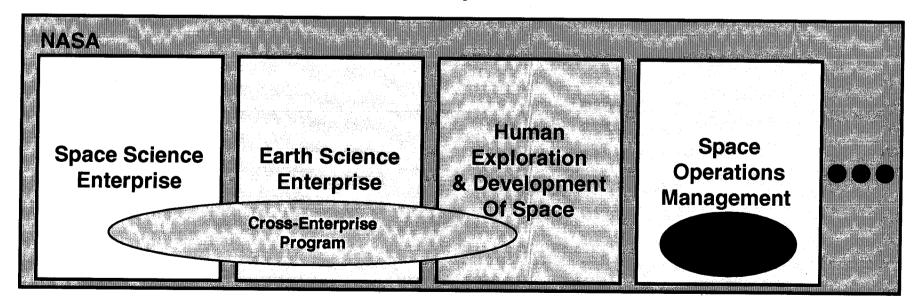
This is my view – there are many millions of others



Inserting New Technology Into Small Missions Far-Term Research



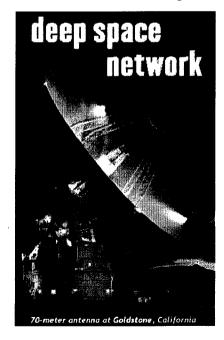
- Crazy ideas are not usually tied to specific missions
- Funding for far-term research tends to be institutional (not funded by individual flight projects)
- Since NASA is organized by "Enterprises" (e.g. Space Science, Earth Science, ...) far-term research programs fall into two categories
 - Enterprise programs (focused on the needs of a NASA Enterprise)
 - Cross-Enterprise Programs
- Both kinds of programs exist currently within NASA

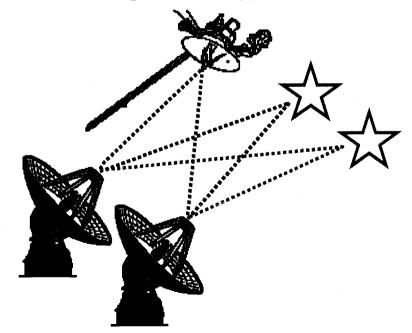


Inserting New Technology Into Small Missions Far-Term Research: TMOD



- JPL's Telecommunications and Mission Operations Directorate (TMOD) leads an Enterprise technology program in the area of communications and navigation
- The TMOD program spans all epochs of technology development, including fart-term research
- Spanning epochs allows a smooth transition between epochs
- However, TMOD must maintain a proper balance between epochs
- TMOD has been very successful in infusing technology

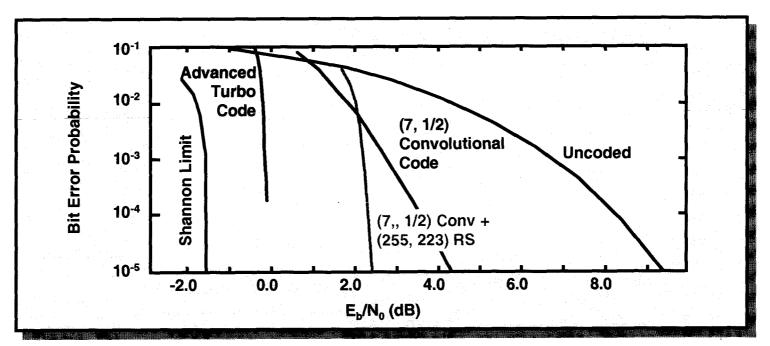




Inserting New Technology Into Small Missions Example: Errer-correcting Kodes



- Error-correcting codes have been used for many years in deep space
- TMOD's technology program has been responsible for many breakthroughs in coding theory and in implementation of coding systems



- TMOD develops the ground equipment and demonstrates the flight capability
- Operational flight systems are developed by flight projects

Inserting New Technology Into Small Missions Example: Cmpresion 4 GLL

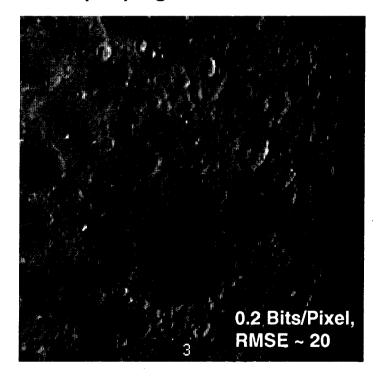


- Before the Galileo mission, deep space missions used mostly "lossless" compression
 - Low compression ratios typically no better than 2:1
 - Well understood, deterministic errors, caused mainly by data overflow

Galileo now uses the Integer Cosine Transform (ICT) algorithm - similar to

JPEG industry standard for photographic images

- Compression algorithms were part of TMOD's far-term research program for several years before the Galileo highgain antenna failed to deploy
- Infusion was fueled by the need to recover a potential data loss of four orders of magnitude
- Infusion took only two years
- TMOD's technology saved the Galileo mission





Inserting New Technology Into Small Missions Far-Term Research – Cross Enterprise Program



- NASA's Space Base Technology program (AKA 632, CETDP) develops technology of benefit to multiple NASA Enterprises
- SBT concentrates on far-term research
- Transition fo subsequent epochs has had mixed success
- Some very big successes have come out of the SBT
- Traditionally, such programs have been assembled from tasks selected locally at NASA centers
- There is a recent trend toward selection by NASA Headquarters through open competition

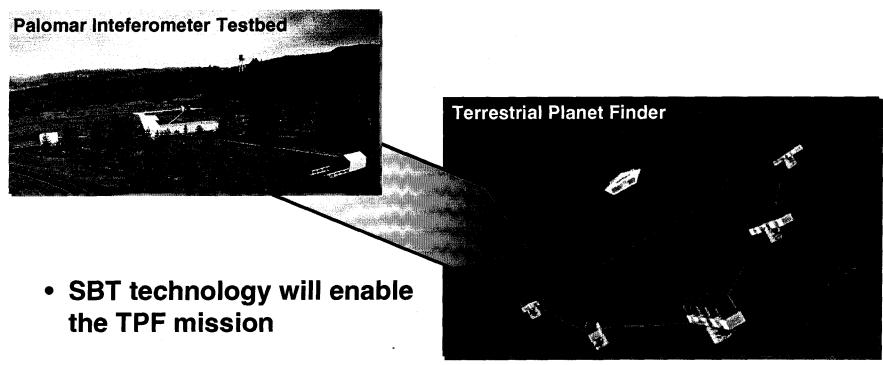
It's the American way

- This insures NASA gets the benefit of the best ideas form all (American) sources of technology
- This makes it difficult to run a cohesive program of related tasks
- This also makes it hard to provide funding stability for research groups at NASA centers

Inserting New Technology Into Small Missions Example: Space Optical Interferometry



- The SBT program developed the concept of a space optical interferometer
- Demonstrated concept on the ground using optical observatories and laboratories
- Transferred technology to mid-term development in the NASA Origins Program
 - Demonstrated feasibility in laboratory experiments

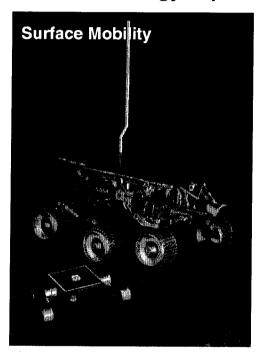


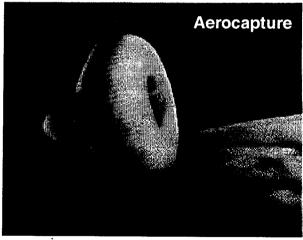
Inserting New Technology Into Small Missions

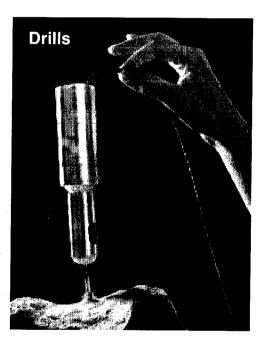
Example: Mars Technology Program



- Mars technologists work closely with Mars mission designers
- Technology requirements are gathered and honed



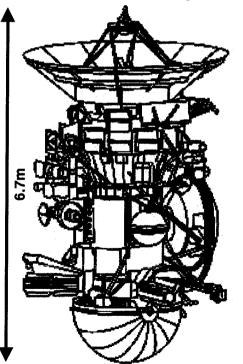




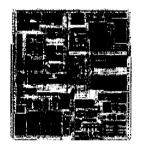
Inserting New Technology Into Small Missions Near-Term Engineering



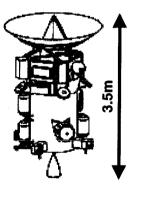
- Typically funded by single flight projects programs, or consortia
- Retire most risk by addressing specific requirements of potential users
- May construct engineering models and prototypes
- The Mars Technology program is a good example of this
- X2000's First Delivery Project as of two years ago was a good example
 - Recently, it was completely merged into Europa Orbiter project



Rad Hard Power PC



Miniature Avionics

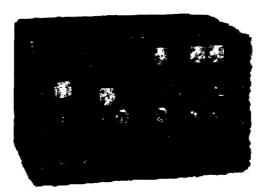


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Inserting New Technology late Small Missions Example: Small Deep Space Transponder (SDST)



- The SDST technology was needed by many missions
- No single mission could afford to develop this epoch of technology
- A consortium was established with many missions contributing funding and oversight
- The SDST is now the standard deep space transponder and is used on all deep space missions



SDST Capabilities:

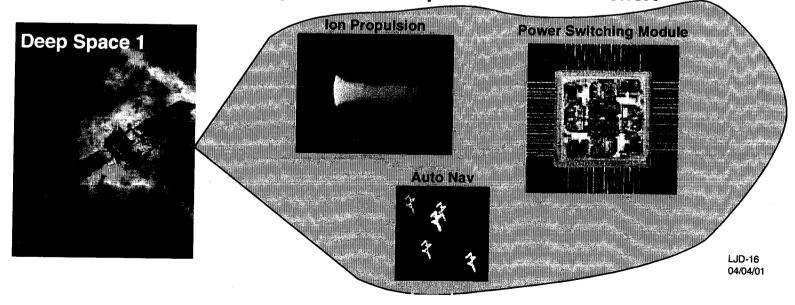
- Deep Space Network Compatible
- X-band Receiver, X-band and Ka-band Exciters
- 2.5 dB Noise Figure (Nominal @25 o C)
- -156 dBm Receiver Threshold
- Temperature Compensated Receiver VCO
- Low Exciter Spurious, Phase Noise and Allan Deviation
- Radio Science Mode (USO Input Available)
- 40 ns Maximum Ranging Delay Variation

- 3 ns Maximum Carrier Delay Variation
- Bus Interface Mil-Std 1553/1773 Options
- External Power Converter Synchronization Capability
- Operates Under Launch Environments
- Radiation and SEU Resistant
- Internal Telemetry Modulation Encoder
- Internal Command Detector
- Mounting in Either of Two Axes

Inserting New Technology Into Small Missions Validation



- Validation of a new technology in a flight environment is often the most costly and time consuming epoch
 - There are not enough launch opportunities to test all new capabilities in space in a reasonable time
- However, nothing reduces the perceived risk to a project manager like validation!
- We must be careful to chose the right capabilities for validation
- We must strive to create more flight opportunities
- The New Millennium Program is NASA's premiere validation effort

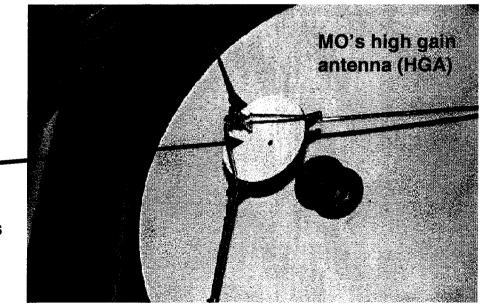




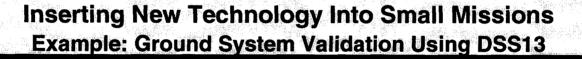
Inserting New Technology Into Small Missions Example: Ka-Band Communications



- The Mars Observer spacecraft carried a Ka-band experiment
 - Although the mission failed, the experiment was successful
- Mars Global Surveyor also has a Ka-band experiment
- These were both flights of opportunity

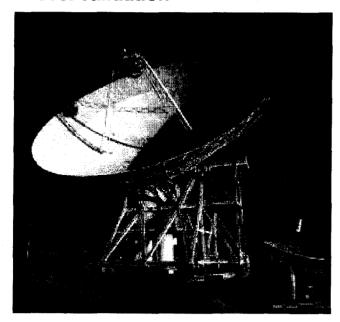


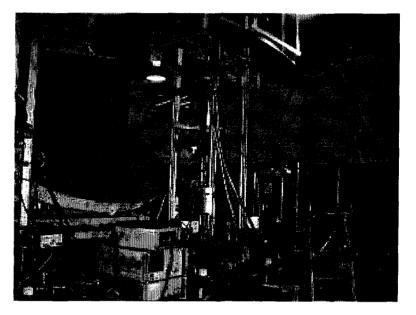
Ka antenna mounted on front of HGA had the same beam width as the HGA at Xband





- TMOD uses a dedicated 34m R&D antenna at its Goldstone complex to demonstrate new ground system technology
- Deep Space Station 13 (DSS13) is designed to allow multiple simultaneous validations in a near-operational environment
- DSS13 can be wired to the rest of the Deep Space Network to do systemslevel validation

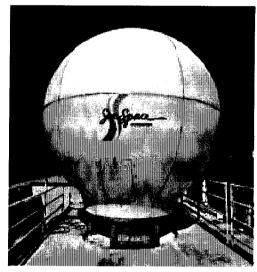




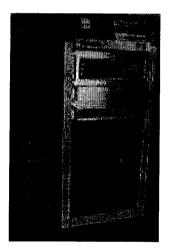
Inserting New Technology Into Small Missions Example: LEO-T Infusion Through Industry



- LEO-T's technology dates from JPL work performed in the 70's with people who eventually formed SeaSpace
- SeaSpace, in the early 90's, sold ground stations that could automatically acquire weather photos from satellites
- Through a JPL collaboration, SeaSpace was able to add the technology to communicate with NASA's spacecraft in Earth orbit
- Now SeaSpace sells autonomous terminals to NASA (through GSFC)



SeaSpace 5m antenna in radome at JPL



Prototype receiver and support electronics

Inserting New Technology Into Small Missions Transition Between Epochs



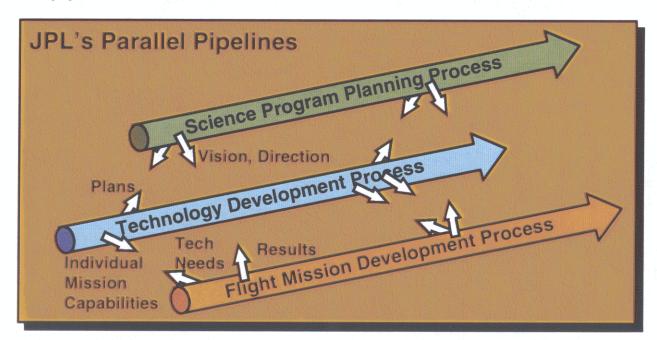
- Technology programs, like TMOD, that span all the epochs have the most success in these transitions
- TMOD's use of a multimission engineering office also makes infusion smoother
- For other programs, these transitions are one of pour major challenges
- Infusion plans should be developed early in the life cycle
 - Stay "plugged in" to the desires of future mission planners
 - Need to focus in on potential applications early
 - Need analysis of benefits, costs, and risks early
- Close coordination between programs in different epochs, and users, is critical



Inserting New Technology Into Small Missions A Model to Follow



- · Technology development does not happen in a vacuum
- We can thing of technology development (with its epochal life cycle) as a pipeline of continuous change
- There are similar pipelines for missions and for science programs
- These pipelines all interact and have influence on one another



Inserting New Technology Into Small Missions Conclusions



- NASA has not found the perfect solution to infusion technology into small missions
- NASA must continue to improve technology insertion in order to succeed at FBC
- NASA's experience with different types of technology programs has resulted in a wealth of knowledge about things that work, and things that do not work
- We have found certain things that greatly enhance the success of technology insertion into missions
 - Solid, stable investment for all technology development epochs
 - A strong mechanism to capture "crazy ideas" from all sources, without stifling NASA's internal creativity
 - Alignment with and advocacy from potential flight users
 - Early planning for transitions between epochs and for infusion